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PART I, Idiosyncratic Systems
PART II, On Being Creative with Computer Aided Design

Nicholas Negroponte
Massachusetts Institute of Technology
77, Massachusetts Avenue
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March 31, 1977

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Abstract, Part I An idiosyncratic system is a personalized computer, intimately acquainted with a specific user. Familiarity is gained over time, through shared experiences, and in context-dependent, interpersonal hypotheses. Personalization offers the possiblity of machine recognition and understanding of conversations that otherwise appear ambiguous, incomplete, or vague. The paper postulates powerful, dedicated, and ubiquitous machines. We present a modest example of how knowing the user can help the computer

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In part II, the author considers creativity in the context of computer aided design.

to recognize his hand-drawn sketches. We suggest some future developments in consumer-oriented applications in education and entertainment. The paper presents not the contours of a well formed theory, but spots of potentiality, application, optimism, and caution.

Abstract, Part II   Computer-aided design is currently enjoying a move into useful application. However, this new productivity is marked by a complete disregard for the notion of creativity. In fact, current CAD systems are not conducive to it.

Following introductions to ~~the history~~ of the paper, theories about creativity, and computer graphics, the paper presents four settings for the computer as a wholesale slave, a virtuoso, a creativogenic tolerance, and a place. They progress from a compliant and partitioned system to well-disposed and redundant surround.

The paper concludes ~~cheerfully~~ with some of the ingredients for highly personalized design systesms, so-called idiosyncratic systems. This is hyperbolized in the concept of the return of the Sunday painter.

Idiosyncratic Systems

Toward Personal Computers and Understanding Context

Nicholas Negroponte
Architecture Machine Group
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Abstract

An idiosyncratic system is a personalized computer, intimately acquainted with a specific user. Familiarity is gained over time, through shared experiences, and in context-dependent, interpersonal hypotheses. Personalization offers the possibility of machine recognition and understanding of conversations that otherwise appear ambiguous, incomplete, or vague. The paper postulates powerful, dedicated, and ubiquitous machines. We present a modest example of how knowing the user can help the computer to recognize his hand-drawn sketches. We suggest some future developments in consumer-oriented applications in education and entertainment. The paper presents not the contours of a well formed theory, but spots of potentiality, application, optimism, and caution.

This paper follows an earilier unpublished paper co-authored with Christopher Herot, and Joseph Markowitz. While only a few examples have been culled from that document, the author acknowledges their specific support and shares most of the following propositions with the Architecture Machine Group at MIT.

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Introduction

This paper primarily lobbies for a good idea, drawing examples most from human-to-human interactions, offering only modest computer implementations. The good idea is simply to have computers know their user(s). The benefits are those we enjoy both in the mechanics of human discourse and in the psychology of individuality. The "idiosyncratic systems" title suggests the extremes to which this author believes we should go. This should not turn off modest implementations desparately needed just to make computers easy and pleasant to use.

The industrial revolution offered a quantitative increase in amenities at the expense of proliferating sameness. The inherent need for amortization through repetition affected human values as well as the physical world. More recently we hear of electronic revolutions, beyond the machine age (Brodey and Lindgren, 1963). But, examples tend to be based on physical variety (like shoes made to order) not on the individuality of communication, thought, and creative processes. There is a sense of anonymity and uniformity in present day computer systems as repetitious, but not as beautiful, as the Crystal Palace.

This author despairs at the lack of research and literature on the subject of personalization except in the passive sense of custom made objects. The sporting of an idiosyncrasy or the drawing of a personal inference remains an unstudied area of personalization. The themes of this paper and the specific research out of which they come postulate that the understanding and development of idiosyncratic systems are crucial to computer science in general and artificial intelligence in particular, given that computational resources are simultaneously more powerful and increasingly inexpensive. This immense resource has implications far beyond the unnecessity of having to share it (Horn and Winston, 1975).

In short, the notion is not only to have or to approximate one-person-one-computer, but to have machines that learn about this person. This is for the purpose of inferring missing information, resolving ambiguities, and overcoming apparent inconsistencies. Our earlier paper on this subject offered the following example from what you might call daily life. Picture yourself returning home after a long and trying day:

"Okay, where did you hide it?"
"Hide what?"
"You know."
"Where do you think?"
"Oh."

Amplification of Individuality

A recent psychological study of personality (Cameron and Mattson, 1972) administered a questionnaire assessing liking of people and pets, a shortened form of the Barron Ego-Strength scale, the Cameron Religious Dimensions scale, and the Eysenok Personality Inventory to matched random samples from the country (n=80), a town (n=306), and three major cities (n=122). In this study of psychological correlates, it was found that town and city females and nonowners of pets claimed to like people more. Pet owners tended to feel less well-regarded by others and to value religion less. Urban pet owners tended to score higher on ego strength. Pet owners tended to like their pets better than people ($p<.07$), while nonowners liked people better than pets ($p<.001$). Results suggest that those who do not own pets are more psychologically healthy than those who do.

Such findings in experimental psychology characterize a quest to compartmentalize human behavior and to establish

normative responses, a pursuit which epitomizes the antithesis of this paper. Here we are concerned with the amplification of individuality, with augmentation and understanding personal styles, and with inference making achieved through totally unique experiences. Computers are construed as able to humanize through personalization, beyond the made-to-order paradigm, more proximate to the understandings humans enjoy in successful wedlock.

In contrast to the search for well formed taxonomies of one kind or another, idiosyncratic systems explore shared, apparently random experiences, where a growth in this common base - acquantanceship - affords the inference making and context recognition that people enjoy in human-to-human discourse, in art, and in mutual confidence. Everyday examples from the world of human interaction range from the modest intents of a good waiter or travel agent, to the more weighty functions of a secretary, to the deep insights of best friends. Oliver Selfridge (in conversation) describes the intimacy of interaction as the lack of it. For a friend, a wink, a gesture, or a metaphor can carry "paragraphs" of information that would have to be spelled out to the passing observer.

Even before the fanciful eventuality of computers becoming so cheap and so powerful that we all have individual, trillion bit, millions of millions of instructions per second computers, with us through life, individualization became a fundamental issue. The issue here is not so much personal computers, but personalized computers. At first this may sound reminiscent of amenities such as the now commonplace features of abbreviation or personal command dictionaries, resident even on some of the most parsimonious time-sharing systems. But then reflect once again upon human discourse where a whatchamacallit or smirk carries enormous chunks

of information that must be decoded, if you will, in context. It is this sort of personalization that must surface in man-machine relations, quite defiant of the traditional classification systems of experimental psychology, quite further reaching than the quantitative advances in speed and economies of LSI, SOS, ROMs and RAMs, that will allow us to proliferate machines, putting them in cars, door hinges and the like.

Our Myth about Interfaces

The myth may be our own, but worth sharing. This author has likened computer aided design to talking about Cezanne to a Martian via telegram (Negroponte, 1975c). The myth stems from a misplaced emphasis on the telegram as opposed to the Martian. It results in part from an obvious disharmony and discomfort in dealing with computers. For a long time, the Architecture Machine Group has been captured by an interest in expressive movements (for example: Allport and Vernon, 1933) as available to humans and unavailable to machines. The tenets of our arguments have frequently revolved about an unsatisfactory and bipartite model of human behavior, reflecting a mind-body distinction.

Yes, unequivocally, machines need more and wider channels into the world to acquire and to share our metaphors. It may be an ultimate requirement that a computer see, speak, hear, and have tactile touch, taste, and olfactory senses, but that is not a sufficient requirement for it to be an idiosyncratic system. This is easily demonstrated in meeting a stranger in a foreign land. While you can hear each other's utterances and see the hand waving and expressions, messages are exchanged muddled if they are understood at all.

Currently a project is beginning (Markowitz, 1975) where the computer recognizes a user by his typing rhythm and, eventually, key-stroke pressures. In parallel with this research, we have proposed (to ARPA, 1975) an idiosyncratic command recognizer that would untangle misspellings and resolve syntactical errors in command lines issued from a keyboard. Given the impoverished and almost sordid nature of keyboards, the experiment illustrates an attempt at recognition and inference making, characteristic of an idiosyncratic system, independent of the richness or lack of it in the medium of interaction. In short, such studies can proceed without the bells and whistles to emulate human sensory systems, but nonetheless be genuine beginnings in personalized computers and understanding acquaintanceships.

Acquaintanceships

Some people use the term "friend" profusely and unconditionally, while others hold it dear and special for few if any. In either usage, let us consider the term as a mark at the other end of the spectrum beginning with stranger. We will call the timeful and bumpy process of moving along this spectrum, occasionally slipping back, sometimes falsely jumping ahead, the process of acquaintanceship. What is the computer paradigm for this experience, currently limited to people and to pets?

Observe the difficulty in making a generalization about a good friend. Knowing the complexities and contradictions of another personality defy stereotyping or generalization without a well-defined context in which to predict the other's behavior. In contrast, after a first encounter, one may find soandso gregarious, articulate, interested, and seemingly well traveled. Or, in a more extreme case, having

never met a particular person, but knowing he is Italian, we might assume (not infer) a cultural stereotype: Catholic, good singer, vowel at the end of his name, likes pasta and red wine.

Traversing this continuum has the intriguing property of reordering representations to the extreme of contradicting and ultimately forgetting initial preconceptions, without necessarily invalidating them. While the cultural stereotype, a human analogue to the default value may help launch an acquaintance, it serves little purpose after a very short period of time. Our new Milanese friend, John Smith, may in fact be a tuneless Episcopalian and a potato loving beer drinker. Or, in the event of meeting Mario Lanza, we rapidly suspend his singing fame from our moment to moment interactions, ultimately from our total view of him. This was recently illustrated in a reference to "the Greek girl" having no identification value to her New Mexican boyfriend. Another illustration can be found in speech defects which, in a very real sense, disappear as you make acquaintance.

The now-popular notion of frames (Minsky, 1974) lends itself well to these initial moments of getting to know somebody. However this computational foundation becomes clumsy and suspect as soon as the nodes and links are so prolific that almost no acontextual paths exist through them. One's representation of another person passes from primarily declarative to primarily predictive, most effective as a situational operator. In an example of man-computer interaction, we can postulate that a computer's model of the user contains frames of what it has inferred to be the user's model of it. It uses this second order model to predict and to fill in missing information, given that we leave out information (even subconsciously) based on the <u>assumption</u> that another person or machine can <u>infer</u> it. This second order model is

constantly rearranged or reinforced through failures or successes in inference making.

Regrettably, there is a third order of model important to acquaintanceship. That is, from the computer's point of view: its model of the user's model of its model of him. It is crucial that this riddle be recognized, appreciated and untangled because the convergence of the first and third order models is an important definition of acquaintance. A friend can be defined as somebody whose model of you and whose model of what you think he thinks of you are asymptocally isomorphic.

Understanding Context

Context is not a setting located in the specifics of space and time, but the meaning an individual ascribes to that setting. It can be said to be the intersection of a specific situation and specific lifetime's worth of experiences. While the situation may be eminently describable, a lifetime is not. This posture toward understanding context is, to say the least, uncomfortable, especially for the computer scientist. Consider the following, perhaps recognizable, story.

> "Made this cookie," said the Monster
> "Smallest one you'll ever meet
> Well, so long, old King and Princess,
> Gonna take outside and eat."
> "Hold that cookie!" Cried the Princess,
> "It's the one I long for. WOW!
> Let me eat your perfect cookie
> And I'll marry you right now."

An artificial intelligence approach to representing and understanding this story would entail an enormous data

structure of assertions (predicates on an arbitrary number of arguments) taken from the story and theorems established "in general". Some very narrow questions about the story might reveal interesting "demons" (Charniak, 1973), the monster being friendly and smallest being best! What is left out is the reader. To a parent of, let us say, a four to ten year old child, the story additionally carries the whole Sesame Street <u>context</u>, including perhaps reproaches of language and insolence. To a child it may <u>mean</u> bedtime. To others, it may just be another child's story and nothing else. The argument is that context is not in the story alone, but our experience with it, perhaps laughs before bed, fantasies of Muppets, or interpretations of meatballs and bananas.

If we are content that context lies in our interpretation of the story, then it follows that we can only share that context with a system of similar interpretive functions. Depending on the "depth" of meaning, the degree of similarity or acquaintanceship will reveal and determine the degree of agreement in interpretation. For example, at a shallow, cultural level, the above story is or is not amusing, much like a joke, based on cultural metaphors analogous to pasta-loving. In a deeper sense, one needs a familiarity with the specific cast of characters and their roles. In the deepest sense of understanding context, one must share a very large set of experiences and witness predictive successes and failures of another's responses. Observe that a child is not necessarily an exemplary idiosyncratic system, especially a younger one, because his "world" is so different. Frequently, the pleasure derived from stories comes from conflicting interpretations. Also, stories provide a specific set of shared experiences through which other contextual issues may be shared.

An idiosyncratic system is a mixture of surrogate you and best friend, for which we have no human counterpart (except perhaps a well seasoned, long standing, analyst). It appears to be crucial that we do not view future computing devices as solely one or the other. A veridical you could breed unimaginable complacency and destroy the human creativity inspired by elements of conflict and contradiction. At the same time, viewing a computer as a self-driven best friend forces us to hobble across epistemological problems, motivation, consciousness, and, in short, a host of philosophical issues that would stymie development for years, if we awaited their arbitration.

Interpersonal Hypotheses

In his most recent treatment of "conversation theory", Pask (1975) illustrates the proverbial syntactic-semantic distinction with the numeral 5 (ie: a chocolate cream pie). He remarks: "5 is a prime number" and "5 is a lucky number." This distinction is clear and, in the case of 13, we can find examples of what you might call a cultural semantic.

Disregarding the presumption of calling our method an "idiosyncratic systems approach" to the number 5, consider that 5 might have been your cabin number on your honeymoon cruise, the number of weeks left to your forty fourth anniversary, or a menu's item number in which you always delight. As isolated facts, these assertions are no less syntactic than "5 is a prime number." What distinguishes them is their use in inference making, interacting with those who know you.

For example, let us assume that item 5 on the menu of Chez Soup is your cherished stuffed veal. When you enter the

restaurant you say "the usual" or you may have to say nothing at all, and the proper dish arrives. From the previous discussion of acquaintanceship note here the completeness of the inference making procedure: 1) the waiter knows that you want number 5, 2) you know he knows, 3) he knows you know he knows. The hypothesis is extremely personal and exemplifies a simple behavior of an idiosyncratic system - the waiter. The illustration can be embellished: as a Catholic you don't eat meat on Fridays (or they don't serve it), in the presence of a lady guest you like to peruse the menu feigning knowledge of all offerings, or in the event of grouse season you will take that when you can.

The waiter story has additional exemplary value. Consider that the restaurant is populated by regular customers. The waiter gets to know each customer's favored dish and correlaries to the rule (if the scenario is elaborated). Given a large enough clientele, does the waiter generalize? Probably very little. It would be foolhardy to presume that blonds tended to eat chicken or that computer scientists enjoyed clams, though maybe it would be appropriate to recommend fettucini to an olive complexioned newcomer. What is important is that hypotheses developed for each client are construed from personal encounters and appear random in nature.

Spouses, lovers, twins, are potentially extreme examples of interpersonal hypotheses, driving the inference making mechanisms being the major components of any interaction. Each of us can think up recent examples (surely not with computers, yet).

In a Computer Paradigm

In contrast to the next section which demonstrates a specific application of idiosyncratic computing, the following section is devoted to general speculation about personalized computers, assuming the reader is familiar with current and past approaches to machine intelligence and interactive systems. We presume a dedicated computing source and will take for granted and not illustrate the intellectual resources and merits in having one's own full-time computer.

Four classes of idiosyncratic behavior surface across the entire panorama of applications, from tools to toys. They include: filtering, inference making, suggesting, and criticizing. The first two are primarily issues of recognizing implicit information and the last two are mostly matters of establishing timeliness. All of them depend heavily upon knowing the user, his manners, his roles, his habits, his situation, etc. Each can be implemented more or less modestly, depending on the degree of acquaintanceship and breadth of knowledge of the user. Initial behaviors might have the flavor of simple courtesy; longer standing roles would achieve deeper intellectual amplification. To offer an example of how poverty-stricken computer science is even in the shallow merits of chivalry, observe that no computer graphics program (to the knowledge of this author) that uses a light pen (alas!) and light buttons has the benevolence to ask (and act upon) if the user is right or left handed.

The filtering function of an idiosyncratic system immediately transcends the domain of courtesy and has far reaching, almost science fiction, implications. A human example of an idiosyncratic filter is a good secretary who, for example, shelters you from unwanted or trivial incoming messages and

edits outgoing signals. On occasion she may even lie (presumably to others, conceivably to you). Later sections dwell on the worrisome implications of a mechanical facsimile. Here we ponder the unapprehensive applications of the personal computer, like: "Answer all my uninteresting mail", "What are the interesting current events?", "Don't interrupt me unless it is important." It is in the definitions of being interesting and being important that reside the aspect of personalization and, note, that the definitions can only be construed in a specific piece of correspondence, current event, or interruption. Also notice that even the best secretary errs on occasion. And finally, we must recognize that filter functions have directions of error that are less critical, where, for example, a new secretary might only venture to answer your junk mail.

The second class of behavior, inference making, is composed of devices used to resolve ambiguities, to fill in missing information, and to resolve apparent errors. On the surface and in spirit, this role is reminiscent of the DWIM (do what I mean) command in Interlisp (Teitelman, 1974). The distinguishing feature of an idiosyncratic approach is that, again, unlike DWIM, it gains proficiency through interacting with a specific user across many sessions. A subset of do-what-I-mean resides in the task of spelling correction. The application is illuminating because, without personal information, the task is almost impossible. Given a known typist, we contend (and have offered to prove) that spelling and typing errors are easily resolved with the inter-keystroke timing. Two examples of personal information, static and dynamic, are: he is a touch typist (versus a hunt-and-pecker), he is a sergeant, he likes skiing; or, he is currently typing the budget (which he hates), his rhythm is characteristic of pondering, it is Friday and the snow conditions are good. Such clues furnish information that a

good secretary manages without much thought. Additionally, it offers search strategies that would not be easily assumed by a human observer, for example, the touch typist meant "now" but typed "mpe".

In the third role, suggesting making, we enter the difficult domain of timeliness as illustrated in human discourse where all too frequently an excellent suggestion receives marginal or negative reception simply because of bad timing. Some researchers (for example, Burke, 1972) have reconciled timing with the merit of hints; however, literature dwells on suggestions from "know betters" (machines or people), who already know the answer or are more competent (by orders of magnitude) to derive it. This flavors the suggestive functions, disregarding the more interesting features of equivocating commentary, which in a limiting sense is closer to poetry. As soon as a suggestion is unequivocal (like: I recommend you compile suchandsuch before you load it) it is truly an inference *making* task and the machine should simply do it. We are reminded of the clever PL/1 compiler which terminates with a single but unrecoverable error and discloses: "You have forgotten a semicolon on line 45 in column 12." More idiosyncratic suggestions and observations are taken from principles of extrapolation and analogy (subject matter dependent, indeed) and used in the framework (frame) of specific work methods. It is hard to offer examples of suggestion making in a creative sense because, after all, people just can't use computers and don't use computers in creative thought, yet. The following and rudimentary example, hardly idiosyncratic, is taken from Nevill and Crowe's (1974) slightly gimicky scenario on an improved cooking utensil (computer responses are shown in capitals):

> Food that doesn't need cooking or plates or utensils
>
> SUSPEND SOME CONSTRAINTS
>
> I could quit eating

IF YOU DO, I ALSO COULD QUIT EATING

What in the world do you eat

NAME A CRAZY WAY OF DOING IT

Take a food injection every month and only eat goodies in between

IGNORE NATURAL LAWS FOR A WHILE

Invent food that cooks without heat maybe

The last role, that of criticism, is only distinguished from suggestions by virtue of being more standoffish, frequently solicited. Often it follows an implicit or explicit "what do you think", sometimes issued simply to gain confidence through compliments, sometimes requested to assure full coverage of criteria, and sometimes asked to provoke a constructive antagonism. Again, we are at a loss to offer computer examples; human examples are commonplace and exemplary of sensitive discussion ranging from benign chitchat to caustic and bitter argument. Consider that a stranger may exhibit undue reserve not to insult or offend. A friend, meanwhile, can navigate through your sensitives and be far more constructive and contributive. From such we should derive a machine paradigm.

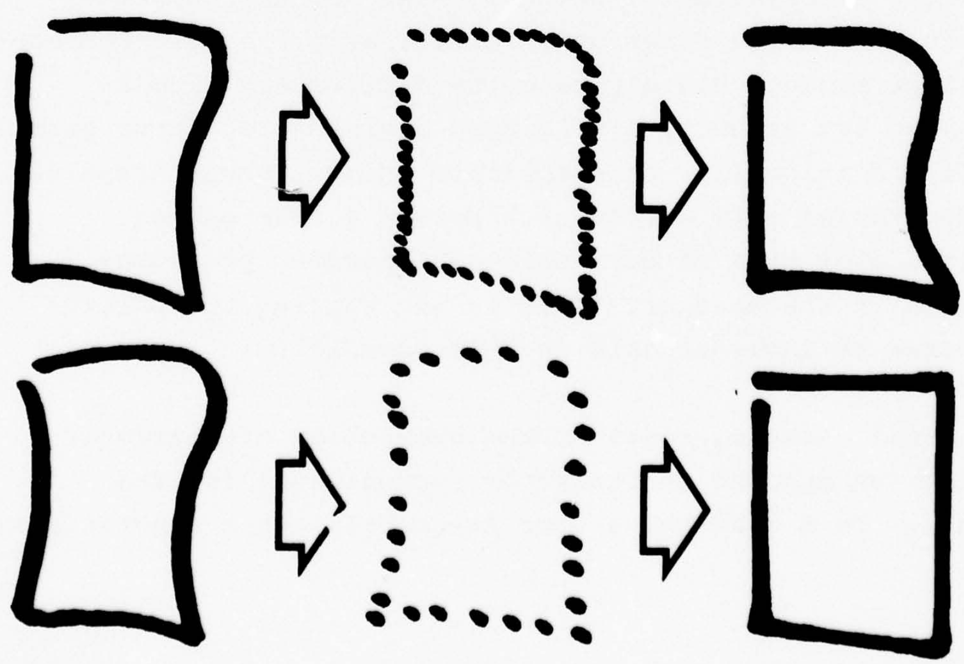
Recognizing Hand Drawing, for example

The following section highlights the ever-present gulf between the noble goal and the specific feasible experiment. It treats an existing computer program and outlines those aspects of its development which relate to an idiosyncratic systems approach. More complete descriptions can be found in Negroponte (1973), Herot (1974), Taggart (1975), and Negroponte (1975a,b).

The problem is to allow a user to sketch freehand with a data tablet (of which there are over ten brands currently

on the market), literally pen on paper, and have the machine properly infer his graphical intentions. The graphics are presumed to be a mixture of projective geometry (the intersection of planes and the delineation of limiting contours) and diagramming (inclusive of textual annotations). The problems include both recognizing the underlying simple geometries of overtracings, cross hatching, doodles, and the like, and recognizing the implications of these (hesitations, for example, are very revealing of worrisome considerations). The motivation to solve this problem (still unsolved in greater part) has its origins in computer aided design, where sketching is a behavior characteristic of a designer at those stages where ambiguities, contradictions, and missing information are indigenous and are not found in the gestalt of a rubber band line.

The input equipment is a tablet that reports "x", "y", and limited "z" values at a constant rate (adjustable between 200 and 400 points per second). This means that the rate at which a line is drawn is deducible from the data. Fast lines have widely spaced samples; and slow, bunched-up samples.



The previous illustration of rectangles is classic; if viewed after the fact, the drawings would appear identical in their intention. However, observed on-line they yield evidence of very different intentions. Inferring these intentions affords dramatic data compression which, in turn, allows the machine to store a succinct and usable representation (approximation). However, it is crucial to understand that this transformation is not motivated by a desire to straighten crooked lines or to smooth wobbly curves for the human, but for the machine. The "sloppiness" has a presumed meaning (hopefully, someday, recognizable by the machine) such that the lines on paper provide the most appropos memory medium for the human. Unfortunately, in sketch recognition we forget this all too often, especially given that we perpetually peek into and display the computer's representation, in part to debug programs and in part to show off.

Given that speed is a clue to intent (slow purposeful lines in contrast to hasty scribbles), the next step is to add pressure sensing to the stylus (in our case 0 to 50 ounces of force on the tip of the pen). Thus, both speed and pressure supply the evidence for inferring graphic intent; still not idiosyncratic, per se. What happens, however, is that each human draws quite differently. A well seasoned architect manages his stylus quite differently from a beginning art student, middle aged engineer, or first grade child. Additionally, to complicate things, these graphical idiosyncrasies vary within each person across subject matters, over time of day, through impending pressures, and even in the weather. This is why knowing the particular user is indispensable in this example.

As a final example, consider the subproblem of character finding (as opposed to character recognition, for the moment). In a drawing, a user frequently makes annotations,

ranging from names, material specification, to unrelated telephone numbers. The problem: separate these (and other symbolic elements, like arrows) out of the drawing such that the remainder has a veritable projective geometry interpretation. Once again, after the fact or unknowing of the user, this is currently far beyond our machine abilities. But, the reader can easily surmise the simplification of the task as soon as we know that it is soandso and watch him draw it. We know his handwriting style, his arrow making mannerisms, and his doodle vernacular.

Futures and Failings

The future of idiosyncratic systems can mean, in a limiting and extreme case, a bleak existence for human beings, incapable of dealing with a world of nature, people, and machines, except through the percepts and interpretations of a mechanical surrogate. This author is all too accustomed to excellent secretarial assistance; as a result he finds it almost impossible to type error free drafts. While his spelling has always been bad, it has certainly degenerated embarrassingly given the practice of an inference making and filtering system that disentangles it. An extrapolation of this syndrome is easily conceived in the framework of personalized computers that do everything for us, including talking to other people (that is, to their idiosyncratic systems). Ultimately, with faultless second guessing, the human is a dispensable component.

More optimistically, an idiosyncratic computer is a personality amplifier, capable of augmenting personal abilities, interests, and artistic tendencies. Such machines could, for example, amplify latent abilities, those we tend to disqualify or pretend to be "naturally" bad at

doing. Similarly, they could furnish intellectual challenge and entertainment, hitherto unseen.

An ultimate future of computers is surely in entertainment and leisure. Current versions of ping pong found in airports or bars, or space-war found in laboratores, are primeval toys, confused by the rubric of game-playing, ritualistic, competitive, and embellished with rules. Russel (1970) shares the opinion that: "The real power lies not in the computer as drudge or censor but within ourselves, when we learn to use it as a toy, to turn on with it and follow a thought or feeling through to the end, as fast as the mind can go." In the same spirit, those readers conversant with writing computer programs (as opposed to using them) should ponder why it is such an absorbing and even entertaining activity.

At this point in time it would be tomfoolery to end with a plea for or against idiosyncratic systems, with a fiction for the future which is either black or white, happy or sad. More appropriate to the immediacies of computer developments, in the light of dropping costs and skyrocketing powers, is a simple urge that we consider the aspects of individualization that some humans enjoy, most don't. Optimism for the future comes from working, where work and play are indistinguishable. The excitement of computation comes from dealing with the simulation of the human intellect. The pleasures and profits of learning can be modelled in the micro-world of debugging. While a great deal can be achieved by giving each man his own DYNABOOK (Kay, 197), LISP machine (Greenblatt, 1974), or Architecture Machine (Negroponte, 1970), the true fruits will only come when these devices sport the fancy of knowing their user better, acting as a new species of friend and toy.

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ON BEING CREATIVE WITH COMPUTER AIDED DESIGN

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Computer-aided design is currently enjoying a move into useful application. However, this new productivity is marked by a complete disregard for the notion of creativity. In fact, current CAD systems are not conducive to it.

Following introductions to the history of the paper, theories about creativity, and computer graphics, the paper presents four settings for the computer as a wholesale slave, a virtuoso, a creativogenic tolerance, and a place. They progress from a compliant and partitioned system to well-disposed and redundant surround.

The paper concludes cheerfully with some of the ingredients for highly personalized design systems, so-called idiosyncreatic systems. This is hyperbolized in the concept of the return of the Sunday painter.

1. HISTORY OF THIS PAPER

The following monograph is a complaint. It laments the absence of any effort to amplify creativity through computer-aided design. Current systems attest to this deficiency by offering no precedent of a person using a computer to be creative, let alone to be more creative than he or she would be without it. In fact, quite to the contrary, we find numerous examples of cases in which computer-aided design deprives us of those dimensions of design that account for its joy and richness. Computers have helped the implementation and execution of designs, as measured by yardsticks of time, of cost, and, on occasion, of quality. But, design *per se* is done off-line, on the backs of envelopes, in the privacy of a daydream, during a walk in the park, through the spontaneity of *cameraderie*.

According to Merejkowski, [35] Leonardo da Vinci, an enthusiast for systems, devised one consisting of little spoons with which different colors were to be used, thus creating an automatic harmony. One of da Vinci's pupils, after trying in vain to use this system, in despair asked one of his colleagues how the master himself used the invention. The colleague replied: "The master never uses it at all."

Such is the state of CAD. Our creative energies as computer scientists are concentrated on the making of better design systems which, while often focused on advancing the comfort and scope of the user, always presume a well-defined task that the unfortunate user must view as a job to be done. We can explain this in part as a cultural phenomenon in the presence of a general American apathy toward creativity; we are indeed a country of doers. We can account for it with the subtleties of human thought and discourse, for example: humor. However, in large measure, we can blame our personal attitudes, frequently selfish and self-serving, toward problem solving, computer graphics, data bases, and the like, which has often overshadowed the more long-range goal of amplifying creativity.

I feel intimately involved with and no less guilty about this state of affairs. Consequently, the following pages are written very much in the first person singular, in the full knowledge that I too shall continue to work on the manageable details of computer graphics and computer-aided design.

The reason I begin with a section on the history of this paper, is that it follows a development that has seemingly (but not in fact) been concerned with the creative use of computers. In 1968 I wrote, [44] "The dialogue of human and machine would be so intimate - even exclusive - that only mutual persuasion and comporomise would bring about ideas, ideas, ideas unrealizable by either conversant alone." In 1972 I followed with, [40] "The intimacy of a dialogue can be in some sense measured by the ability of each person to recognize the intentions of the other." But this time, baroque language was accompanied by pragmatic research and modest developments, namely, in sketch recognition.

Sketch recognition is as much a metaphor as a fact. It is illustrative of an interest in those areas of design marked by vagary, inconsistency, and ambiguity. While these characteristics are the anathema of algorithms, they are the essence of design. The recognition of hand-drawn sketches has been reported on by me and other, [42, 64, 22] but the reader should not wander to that literature hoping to find the problem solved. Instead, it describes an important step toward personalized computing. I coined the term "idiosyncratic system" [37, 39] to distinguish a personal computer from a personalized computer, one that knows its user intimately and can accordingly invoke all the necessary inferences to handle vagaries, inconsistencies, and ambiguities. I offered the following hypothetical scenario as an example:

> Okay, where did you hide it?
> Hide what?
> You know.
> Where do you think?
> Oh.

The pursuit of personalized design aids is stymied by a complete lack of input from the work and literature of exerpimental psychologist, who are far too engrossed in normative behaviors. Only when an idiosyncracy goes too far, i.e., deviancy, [14] does it get attention, and then usually from psychiatry. A notable exception is the work of Pask [48, 49].

Historically, Arthur Koestler [25] offers the following anecdotal example of the first recognition and application of an idiosyncratic system. Apparently, in 1796 a minor scandal occured at the Greenwich Observatory: the astronomer Maskelyne dismissed one of his assistants because the latter's observations differed from his own by half a second to a whole second. Ten years later the German

astronomer Bessel read about this, puzzled over the frequency of similar timing mistakes, and initiated a ten year comparison of his own records. Bessel was able to prove that there existed systematic and consistent differences between the spread with which each astronomer reacted to observed events and he succeeded in establishing the characteristic reaction time - which he called "the personal equation" - of several of his colleagues.

More recently, Williams and Rimland [73] have underscored "individuality" from the point of view of psychiatry, neurology, and psychoanalysis.

Turning to creativity, I find a larger volume of literature, populated by a larger number of disciplines. The following pages deal with areas of intersection between part of this literature and my own experiences with computer graphics and computer-aided design.

2. VIEWS ON CREATIVITY

Writings on creativity are numerous. Silvano Arieti's recent book *Creativity, The Magic Syntheses* [1] has 384 entries in the bibliography. Gordon's famous *Synectics, The Development of Creative Capacity* [20] has 351. Only 13 entries on the subject appear in both! This illustrates a dramatic lack of common reference to and common postures toward creativity and, in some sense, characterizes a lack of consensus which surrounds the topic. As a newcomer, I take license to classify these theories, somewhat according to their age, as philosophical, psychoanalytic, psychological, and industrial (for lack of a better word). I am purposely avoiding (for the moment the alternate taxonomy, ordered by discipline - art, science, engineering, and the like.

Philosophical positions on the topic of creativity are distinguished by being venerable, but not particularly useful. According to Vincent Tomas [67], when one asks the philosophical question, what do we mean by creativity, we are not looking for historical information about the habits of great artists; nor for the personal and social conditions most conducive; nor for the psychological explanation. Rather, he argues, "one is asking for a clarification or analysis of the *concept* of creativity" (the italics are his). The classics offer us very little on the topic. Only the accidental is new in the world of Aristotle; it is no wonder that he had to reduce creativity to imitation. [18]

Psychoanalytic theories of creativity understandably start with Freud's contribution of the importance of unconscious processes, especially of unconscious motivation. However, Freud was almost exclusively concerned with motivation in creativity as opposed to the essence of creative behavior itself. Only much later did his primary processes gain the attention of psychiatrists, particularly in regard to creativity as the product of the preconscious and not the unconscious. [26, 27] Arieti [2] introduces the notion of a tertiary process to designate the special combination of primary and secondary mechanisms of strict Freudian doctrine. He further introduces and coins both the term "endocept" to title the nonrepresentational activity of the psyche and the term "paleologic" to describe a seemingly illogical form of thinking; two concepts important to creativity. The following sections on the setting for using CAD as a creative tool owe a great deal to that particular author, especially to the notion of a creativogenic (his adjective) machine. However, my perusal of this literature leaves me with an uncomfortable (but understandable) sense of correlation between creativity and insanity. [31, 24, 28, 54]

A more sanguine attitude can be found in psychological theories. Joseph Wallas [69] is held to be one of the first to give the creative process attention. He advanced a four-stage process of *preparation, incubation, illumination, and verification*, which received both confirmation [51, 42, 53] and elaboration. [58, 66, 64] However, many authors, for example Beloff [3] and Westland [70], agree that the turning point was J. P. Guilford's presidential address to the American Psychological Association in 1950, titled *Creativity*. Guilford emphasizes divergent thinking and advances the hypothesis that creativity as a cognitive function is to be distinguished from intelligence (the tests for which have consisted almost entirely of items which measure the ability to think convergently).

Finally, what I call the "industrial" attitude toward creativity borders on application-dependancy. It is meant to distinguish a body of literature pertaining to neither the fine arts nor the academies of science, but to more routine endeavors, frequently called "problem solving." Paradoxically, it is this body of literature which most overtly relates to design, notably Osborn's [46] *Brainstorming* and Gordon's [20] *Synectics*. I say "paradoxically" on three counts. For one, I contend that design is not problem solving, but is what several authors (including myself, [44]) have called problem worrying. For another, the examples from this fourth category of literature dwell on group processes, which in some endeavors are unthinkable; for example, we cannot imagine Michelangelo's *David* or Picasso's *Guernica* as the result of teamwork. Finally, aloneness is the first condition for the cultivation of creativity considered by Arienti, [11] whereas CAD is a team (of at least man and machine) by definition.

On certain issues, there is agreement among these writers, namely on the Jekyll-and-Hyde nature of judgment and imagination, which demands that the critical mind be suspended lest it hinder the production of ideas. This involves, one is told, the merging of disparate contexts, making the strange familiar and the familiar strange. In a celebrated lecture to the Societe de Psychologie in Paris (quoted in Ghiselin [17]) Henri Poincare states: "Among chosen combintions the most fertile will often be those formed of elements drawn from domains which are far apart .... Most combinations so formed would be entirely sterile; but certain among them, very rare, are the most fruitful of all."

Another area of agreement truly violated by current design systems is the need for tranquility and lack of disturbance. One author goes as far as to postulate that the "conditions for poetic creation are also the optimal conditions for scientific creation." [72]

3. COMPUTER GRAPHICS

This section is limited to those specifics of computer graphics that can be viewed as both metaphors and facts. The detailing of a current swing away from a dismal past, particularly away from a static graphics, is reported elsewhere. [40] Computer graphics originated with considerable ambitions [11] of bringing the act of design into the realm of computer aids. However, even the most enthusiastic user of CAD will not argue that we have arrived yet at that point. Instead, almost to the contrary, we are increasingly locked into a paradigm of automation which services the details of graphics and data management in the name of liberating the designer to design.

Computer graphics offers a rather lopsided augmentation of our vision and gestures. Certain aspects of innovation provide design aids hitherto unimaginable, while others do not even approximate the

richness of pencil and paper. For example, the dynamic, and even static, embodiment of a three-dimensional construct allows us to view designs as never seen before. On the other hand, the gentle and inquiring texture of graphite on paper is unavailable to us. Too often we disregard these anomolies of automation, in favor of saturating our senses with new perspectives. But note that "many creative persons want to be removed from excessive stimuli." [1] I will contend that those stimuli present must be in concert with both the nature of the involvement and the nature of the person.

An example I have used over and over can be found in the dimension of color. Color is increasingly removed from our lives, notably by printing costs and office copying machines. (An important exception is television. A current trend is television-based graphics [37] which, among other advantages offers color at almost no cost.) My example has to do more specifically with the endeavor of writing. At home I compose a document on an old electric typewriter (as I never handwrite), the kind that looks much like a 1950s Buick and has a red/black cloth ribbon. When carried away by something even as dull as a memorandum, I may type particular words in red, to bring them to the attention of the reader, even at a glance. Subsequently, at the office, this is transcribed with a fancy, correcting, 15-inch platen Selectric with carbon ribbon. Carbon ribbons only come in black. The result is the substitution of an underscore, change in type, or some graphical ploy. My point is not to bemoan the removal of the dimension, but to claim that I would have written the document differently in the absence of color, perhaps surrounding the important words with heated adjectives.

Similarly, in computer graphics we are constantly driven, sometimes unconsciously, to consider those aspects of a problem which lend themselves to the various and circumstantial dimensions of the hardware at hand. This is particularly noticeable in graphic design, where page layout systems (until recently) could not display high-quality text or photographic material. Consequently, the market has offered hyphenation and justification (the infamous H&J) packages for the production of proof in a most conventional, off-line manner.

As a final note to this section, I will question the well-entrenched notion in computer graphics of a "window." The inception of the idea stems directly from the physical size of cathode ray tubes and indirectly from their poor to modest resolution. The idea simply considers the display to be a porthole into a sea of data which can be translated and scaled, bringing various amounts of grpahical information into view. In a very real sense, the user chauffeurs himself about his graphical space, in more complex systems with a three-space. I have likened this to the blinders worn by horses which pull anachronistic carriages down Fifth Avenue. The failing is threefold. One, you have to know where you are going to get there. Two, the panorama, mostly in the fovial vision, is composed of an *a priori* signal-to-noise ratio. Three, the framing in a physical sense is a true cramp.

Later sections will offer alternatives, specifically, the concepts of ambient information, graphical place, and sensory pruning. Instead of considering our design aids as peepholes into computers, I suggest we think more spatially, filtering data in manners not cartesian. I am reminded of seeing a familiar city for the first time at night or, in reverse, a ski resort during the summer.

4. THE MACHINE AS A WHOLESALE SLAVE

In discussing computer graphics, Coons [10] refers to "an idiot-slave model of a fast draftsman who doesn't eat." This simple metaphor is the facade of a very complex paradigm of man-machine interaction, to which most of us ascribe, whether or not we admit it. It is a mascot for those who dispute the advisability or feasibility of developing an artificial intelligence. It is the common denominator of current CAD.

More speculative approaches to CAD include commitments to machine intelligence, yet to be fulfilled, and consequently vulnerable to criticism. The purpose of this section is not to champion a current cause, but to contrast it with the concept of a slave. Important concepts for amplifying creativity are found in the distinction between manipulating ideas as though they were things. [36] The machine as a wholesale slave lends itself to many aspects of thing-manipulation, but not to critical tasks of generating, evaluating, and, most importantly, understanding ideas. Instead of pursuing the large epistemological problems of these concepts (that has been done eloquently by Pask [49, 48]), I will dwell on two particular details of the slave paradigm in CAD, namely, that of *partition* and that of *compliance*. I see these as the two most important deterrants to the creative use of CAD.

The idea of a well-formed partition between what the human does and what the machine does can be traced to cocktail chatter: "Let the machine do what it is good at doing and let the human do what he or she is good at doing." We recurrently find example examples: observe how few of us can recite the alphabet backwards or how no machine can distinguish Der Fliegende Frankfurter from an airborne sausage. Horman [23] gives some account of this in her paper *A Man-Machine Synergistic Approach to Planning and Creative Problem Solving*. My concern about the partition is caused by the lack of redundancy of tasks. When each party is doing that and only that in which he, or she, or it, is expert; a premature sense of completeness arises, and a premature critical judgement is invoked.

I am thinking in particular of graphical exactness. My position is exemplified in problems of graphical input, where I will claim that the wobbliness of lines in a sketch have an important gestalt in relation to one's current thinking about the design of which that sketch is a representation. Further, hand-movements and hestitations, before stylus hits paper, reveal senses of completeness, certainty, transciency, and the like. In contrast, in CAD we are forced to think with an expert draftsman, on occasion with insidious rubber-band lines. What this does is to create a false sense of exactitude and consummation, which in turn discourages the bantering of alternate strategies. Ironically, CAD was supposed to allow for the study of more design alternatives. Instead we find a more rapid zeroing in upon one.

We have seen in section 2 that a major consensus prevails regarding the desirability of suspending critical judgment during the time of incubation and production of ideas. This suspension is exceptionally difficult when one is presented with a contradiction to a "fact of life," at least a seeming one. For example, in a well-partitioned system we could never live with a machine-aided mathematics, using the term; "lowest common denominator." The term is a blatant contradiction in that what we mean is the highest common denominator (but we all know that in a large set of numbers, it is usually low). In other words, the wrong idea is in some sense right, and in this example, has even assumed cultural acceptance.

Turning to the notion of cultural compliance - maybe better termed acquiescence - we find a host of trite examples of machines that blindly execute stupid commands, all of which require one of two extremes, either an "understanding" or a special-purpose trap in order to be avoided. I am less concerned about the kind of compliance that may cause robots to jump out of windows when told then I am in the strategic singlemindedness that goes hand in hand with it. By this I mean the ability to view a problem in different ways even though there is a brute force, an eminently "do-able" way that does not require any "effort" or originality. Consider the following example by Karl Dunker [13]:

Two trains are a hundred miles apart, separated by a straight stretch of track. They start moving toward each other at twenty miles per hour. At the same time, a bird perched on one of the trains for some unknown reason starts flying toward the other, at thirty miles per hour. Upon reaching the advancing train, it turns around and flies back to the first, whereupon it reverses its direction, back and forth, and so on. The question is: how much distance did the bird cover, flying back and forth, until the trains met?

A compliant computer will grind out the sum of the series and, yet worse, probably will not interact with the user in any manner except to expedite this sum. A more creative solution to the problem is to take it out of the contest of *space* and put it into *time*. Obviously, or not-so-obviously, the trains required two and a half hours to meet. We see at once that the bird must have also flown for two and a half hours and hence covered a total of seventy-five miles.

5. THE MACHINE AS VIRTUOSO

Consider the notion of the Renaissance machine.

Leibniz is said to be the last person to know everything. However, Arieti [1] (who, out of 487 references to authors, artists, scientists, luminaries, never mentions him) makes a case that such people do not exist. He argues that the notion of a Renaissance man is vacuous. For example, Leonardo da Vinci's life as a scientist and engineer is filled more with frustration than accomplishment. His airplanes, submarines and diverting of the Arno river were undertakings that failed, especially in comparison to the Mona Lisa or The Last Supper. Similarly, Alberti reached his greatness in architecture, even though skilled in music, painting, poetry, Latin, and philosophy.

The question of this section (mostly unanswered), in complete contrast to the preceding, is simply: in what ways is creativity enhanced or subdued in the presence of a machine posed as an incontrovertable savant? I am reminded of my father's painting, which suffered more than benefited from my critiques based on the minutiae of perspective construction.

Two seemingly debilitating personal characteristics are attributed to the creative personality: gullibility and, for lack of a single word, the tendency to jump to conclusions with insistence but without proof. Rothbart [59] expands the former in the context of engineering. Polya [56] states: "When you have satisfied yourself that the theorem is true, you start proving it." The English anatomist Harvey and the Russian chemist Mendeleev are examples. Harvey postulated the existence of capillaries (before the microscope was developed into a serviceable tool), but could not prove it. Thirty-three years after the publication of Harvey's book (in 1628) his explanation of the circulation of the blood was proved by Marcello Malpighi (who discovered capillaries in the lungs of a frog). Similarly, Mendeleev was successful in the design of his Periodic Table of Elements (announced in 1869) by virtue of not being deterred by serious shortcomings. When he could not place an element in his table he was content to leave the entry blank and to predict the future discovery of an appropriate entry. In less than thirty years his prediction came true with the discovery of gallium, scandium and germanium.

If we view the problem as the amplification of creativity in design, a revealing distinction is found in the difference between a hunch and a hint. According to Platt and Baker [55]; (I cannot find a more current reference to this topic): "A hunch springs from a wide knowledge of facts but is essentially a leap of the imagination, in that it goes beyond a mere necessary conclusion which any reasonable man must draw from the data at hand." A hint, meanwhile, is the caricature of paternalism and accordingly demeaning.

Most computer-aided design systems are more like hint-giving systems than hunch amplifiers. The notion of an *incompatibility*, even of my own design, [45] is vulnerable to this hint-giving paradigm. "In the ideal situation, the communication language could be so informal, that is, so natural, that the computer-aided designer would not have to learn it .... If an *incompatibility* is found, the designer concerned would be informed." [21] The italics are my own. Maybe that is not so ideal. My concern stems from three problems with CAD systems: that of timing, which can be managed; that of thwarting the "creative leap," which may not be manageable; that of paternalism, which might be a built-in contradiction to the intention of using CAD for creative purposes.

The timing of a remark is frequently more important than the remark itself. Subsequent sections will argue that such timing is aided by an intimate acacquaintance with the designer. Here I am more concerned about the propriety of keeping quiet. Three important references to the influence of timing are found in Maier and Burke, [33] Burke, Maier and Hoffman, [9] and Burke. [8] Some of their conclusions include: the behavior engaged in at the time a hint is received will determine the way in which the hint will be interpreted and used; when the ongoing behavior is at odds with the information provided, the individual will attempt to find a new approach that is compatible; the timing of the hint does not influence subsequent problem-solving activity. It is the last that is most disturbing. The explanation may be that the problem-solving approaches in this body of literature may be oriented toward exercises of ingenuity, as opposed to creativity.

For example, consider the so-called Hat Rack problem. The task is to design a structure sufficiently stable to support an overcoat, using two sticks (1" x 1" x 60" and 1" x 1" x 43") and a 2" C-clamp. In this example, hints are used to overcome faulty presumptions like: a hat rack is a vertical structure that rests on the floor, or, the coat must be hung from one of the sticks. This is because the only stable solution consists of clamping the two sticks together so that they may be wedged between the floor and ceiling, using the clamp handle as a coat hook. Are not the more creative solutions in complete contradiction with the fabric of such an experiment, that is, to dwell upon overcoming the limitation, in some sense breaking the rules, (maybe even the sticks)? It is, in fact, in these violations of the given that one finds the framework for creative leaps.

I have implicitly likened a hint to a machine constraint. More explicitly, hints presume a know-better, as do constraint resolvers of one kind or another, which determine and post conflicts or incompatabilities. In the environment of the virtuoso

machine, one need only remember (and worry about) one of the few domains of consensus about creativity, namely, the suspension of critical judgment in moments of collaborative effort to find that for which you do not know you are looking. Osborn [46] argues strongly that the premature intrusion of judgement (note the issue of timing) aborts the ideas which could prove to be most valuable. I am worried that the machine as a virtuoso is prone to such intrusions, at least as a metaphor for one style of work on CAD.

This last question, that of paternalism, cannot be solved, only broached. It is a riddle with paradoxes, as much emotional as rational. I am reminded of a formidable PL/I compiler that concluded a bug-full compilation with a list of errors of the sort, "semi-colon missing following ELSE of the third nested DO on line 36, column 18." At first one is irritated by the exhibitionism and wonders why such cleverness cannot simply be deployed to fix the bug automatically. Then one worries about the occasions when the compiler is wrong. And finally one despairs at having to use such a denatured language in the first place.

As a concluding example, I submit a very delicate problem inherent in one of our current research projects: Architecture-by-Yourself. [15,70] The problem is to build a computer-aided design system for a future homeowner, presumably (though not necessarily) in a high-density setting. The problem is to avoid railroading the user into decisions and to act only as an early warning system. This is achieved with a very passive computer, asking few questions, tallying the consumption of energy, materials, dollars, and the like. How does one encourage new ideas and broaden insights without paternalistically inducing solutions that are in no way a reflection of the user's needs? I do not know. But I do know that question-and-answer lobbying is not the correct solution. I offer the following as an example of the virtuoso machine doing *damage* [57]:

Computer:	Shall we discuss the dining areas?
User:	Yes.
Computer:	Who does most of the cooking in your family?
User:	Carol.
Computer:	I would suggest that the dining area for your everyday meals be in the same room as the cooking area so that everyone can socialize while meals are being prepared and Carol won't be isolated in the kitchen. Don't you agree?
User:	Yes.
Computer:	How often do you want these occasions to be formal (that is, other than casually joining you for dinner) in times per year?
User:	Twelve.
Computer:	Keeping these answers in mind, do you feel that you need a separate dining area for more formal occasions?
User:	No.

6. THE MACHINE AS A CREATIVOGENIC TOLERANCE

Coons [10] states about CAD: "The central issue seems to be how to endow the machine with that undefinable capacity called *"understanding."* The evidence of *"understanding"* in humans as well as machines is some intelligent response that is *"meaningful"* and pertinent; although not necessarily *"right."* I am reminded of a child's explanation of the wind. His theory was the the trees waved their leaves and caused the wind. However *"wrong"* this is, it would be wonderful to have a machine intelligent enough to invent such an essentially logical idea."

Such ideas are not only the delight and fancy of children, but frequently the origins of important theories. One need only consider Aristotelian physics, which lasted until the Renaissance, sustaining such explanations as, stones fall to earth because it is their natural home, and, flames rise upward because their home is in the sky. Arthur Koestler [25] recounts an example of a situation in which "correct" ideas were not tolerated. The incident involves the Viennese doctor Ignaz Semmelweiss, who discovered that certain infections were caused and carried by the unwashed hands of surgeons and medical students. Consequently, he introduced the strict rule of washing in chlorinated water, which dropped the death rate first from one in eight to one in thirty, then one in a hundred. Subsequently Semmelweiss was hounded out of Vienna by the medical profession for daring to suggest that they carried death on their hands. Exiled to Budapest, he denounced his opponents as murderers. Receiving little attention, he became raving mad, was put in a straitjacket, and died in an asylum.

While it is hard to liken a computer system to the Viennese medical profession in 1850, it is easy to parallel a momentous intolerance, for "right" as well as "wrong" ideas. I can remember numerous occasions of feeling frustrated by an uncompromising, inflexible, dumb computer. Intolerance for typographic inaccuracy is in itself sufficient to illustrate the complete opposite of a creativogenic environment. I have frequently wondered how many people have been driven crazy, not quite to the extreme of Semmelweiss, by the substitution of a lowercase "L" for a one, something we have done all our lives with typewriters and something for which there is no convention like slashing a "0". (I admittedly can never remember whether Ø is a zero or an O.)

Very few authors study creativity in terms of encounters with people and the environment. Instead, there is a *de facto* agreement and emphasis upon the need for aloneness, tranquility, introspection, but particularly aloneness. An exception is found in the work of Schachtel, [60] who roots creativity in people's need to relate to the world around them. He writes: "The quality of the encounter that leads to creative experience consists primarily in the openness during the encounter and in the repeated and varied approaches to the object, in the free and open play of attention, thought, feeling, perception." It is clearly the case that no encounter with CAD can be characterized in Schachtel's terms, and it would be supercilious to nag about this inadequacy. Even as an orthodox believer in artificial intelligence and researcher in this very field, I am willing to wait. In the meantime, are there models for the machine as a creativogenic tolerance?

The most encouraging techniques are coming from computer-aided instruction, in particular, from those researchers who are bent upon amplifying learning through playing. Initiated by Papert, [47] a student of Piaget, this attitude toward what you might call creative learning is receiving overdue and popular acceptance. The notion can be abbreviated in the cliche that the best way to learn something is to teach it. The machine is consequently an intellectual playground in which the child debugs his own models in the light of differences between anticipated and exhibited behavior of the machine.

In design, such play may be the key to the inspirational facets of CAD. Berlyne [5] goes as far as to state that play "includes everything that is classified as recreation, entertainment, or "idle curiosity," as well as art, philosophy, and pure (as distinguished from applied) science." In design

schools we are struck by the amount of dog-work that accompanies the process of creation. A variety of wisecreacks exist about the disproportionate amount of perspiration required for small quantities of inspiration. The very basis of CAD is to remove this drudgery, to change the balance, and to afford the opportunity for greater inspiration. It is here that we must be very cautious.

I consider architects as very tactile people. Removing all the toil is not necessarily a good thing. In fact, we may want to consider putting some of the handicraft back into design, still in concert with a computer, not just removed in the name of efficiency. In a very therapeutic sense, I propose that there must be a tolerance for manual and graphical (in the case of architecture) sport and fascination, as things unto themselves. This is similar to a respect for daydreaming.

Osborn [46] calls daydreaming "the most common use of noncreative imagination." Here I must disagree and side with Singer [62] and Arieti [1] who share the position that "persons engaged in daydreaming would be characterized by a considerable exploratory tendency." In fact, we find some evidence that daydreaming leads to the unilaterally accepted creative-promoting condition of so-called free thinking. But don't be caught daydreaming in front of your terminal!

7. THE MACHINE AS A PLACE

This last section must be read in two ways: literally thinking of machines as places we inhabit [42], and considering an intellectual milieu of ambient information. [7] Both depart dramatically from current systems, all of which are highly directed and directional, in both their mechanics and their conception.

However, before postulating such a place, consider some accounts of creative environments, though admittedly passive (sometimes peculiar). *For example*, we are told that the poet Schiller liked to have rotten apples, concealed beneath the lid of his desk, under his nose when composing poetry. [63] A more common environment seems to be the bed, where Einstein, Descartes, Cannon, Poincaré and Brindley claim to have had their most profound ideas. [6] Helmoltz claimed that his inspirations came "never at the writing desk." [74] "In order to be creative Thoreau built his heritage, Proust worked in a cork-lined room, Carlyle in a noise-proof chamber, and Balzac wore a monkish garb; Gretry and Schiller immersed their feet in ice-cold water; Guido Reni could paint, and de Musset could write poetry, only when dressed in magnificent style; Mozart, following exercise; Lammenais, in a room of shadowy darkness, and D'Annunzio, Farnol and Frost only at night. The aesthetician Baumgarten advised poets seeking inspiration to ride horseback, to drink wine in moderation and, provided they were chaste, to look at beautiful women." [30] Several authors have had recourse to bathtubs. The ludicrous extrapolation is that of a waterproof, odoriferous, equestrian, noiseless computer.

With the exception of the last qualification, noiseless, these settings are more eccentric than practicable, eclipsing the primary purpose of featuring aspects of the environment, seemingly unrelated to computers. But, are they really so unrelated? Is there a germ of truth in the consideration of work <u>places</u> rather than work <u>stations</u>?

In relation to my introductory remarks about computer graphics, I will contend that the first kernel of truth comes from a multiplicity of media and extensive motor involvement with them. I am told of the admiral who delighted in reconfiguring formations of press-pin ship figures on a large bulletin board map. When presented with a formidable, tactical (definitely not tactile) computer system, he refused to use it, forfeiting information management for the bodily involvement with his vessels. This was not for sportsmanly reasons, but because he remembered his actions as body movements, not as coordinates. I believe that this example has relation to computer-aided design.

It is not infrequent to conduct design reviews by posting a set of large drawings around a room and to wander from section to plan to perspective back to plan, and so on. This is a very literal example of "surround," emulatable by computer, at some expense. The multiple drawings are in some sense less important than the feature of wandering and the notion of <u>large</u>. My eye becomes the window.

Immediately one worries about an information overload, a plethora of details, and a potential for overstimulation (which the psychoanalytic literature on creativity strongly warns us against). Consequently I offer the notion of sensory pruning, versus spatial limitation. The latter is characterized by current "window graphics" with the proverbial powers of zooms and spatial translation. The former has no precedent yet. In fact, it can be said to be the subject of my current research, starting at this writing (to be presented orally at IFIP Congress 77).

The reader will remember two earlier examples briefly mentioned: seeing a city at night or a ski resort in the summer. These illustrate sensory pruning and "un-pruning" in a very direct way. In the case of a city, cluttered with detail, color and frequently unsettling features like dirt, smog and ugly buildings, it can become very beautiful at night, predominantly black and white in the background, with most elements of form reduced to the hidden scaffolding for a sculpture of light. In reverse, we can imagine the winter-palace nature of a ski resort giving way to bucolic clutter.

A fuller analogy in spatial references is *perhaps* the fog to which we can all relate on land, at sea, or on Baker Street. A dense fog not only decreases our depth of field, but increases our sense of hearing. If we consider our data (as well as our computer) as a place, and if we know we are looking for a "file" with particular sound characteristics, it is quite logical to induce fog to find it, much like a blindfolded kidnappee attempting to retrace an abduction. I will call this *sensory pruning* in contrast to the notion of a window, *sensory framing*.

Is this a helmet, a room, or a football field of apparatuses? Regardless, what is critical is the notion of free body movement, not the solemnity of being posed in front of a keyboard. Additionally, I am presuming a variety of force feedback systems to insure complete tactile interaction, as well as light/sight and sound/hearing. Here are two examples, both taken from experiments underway which use a large digitizer/plotter (Computervision's) retrofitted to have the relation of the transducer to the servos under program control. In one case, planning a path on a topographical map (in color, etc.), the high-frequency response of the handheld puck allows the user to feel the terrain as reported by data on rockiness, marshiness, and the like. Or, less tactually iconic, consider the assignment of an arbitrary dimension to the force required to digitize. In this example, we can *imagine planning a highway* where the drawing of proposed routes in increasingly more difficult as a function of the number of families being displaced.

As a final point in regard to the computer as a place, a design place, it is important to expand sensory augmentation and sensory pruning to include the general notion of filters. Our perceptual

system itself is a filter and reductive. Given a universe of potentially numberless stimuli, one is constantly filtering information in both primary and secondary ways, in the Freudian sense. With directed attention we manage to locate a screwdriver on rocky ground or discriminate an old English sheepdog lying on a Flokati. More relevant, perhaps, with primary processes we find the ability to latch onto unexpected cues, like overhearing one's *name* at a cocktail party, when it was in fact mentioned in a low voice, in the distance, well below local and ambient sound levels. Or, as a final example of primary filtering, I offer a personal experience that many readers may have shared in one fashion or another. It has to do with cars. I recently purchased a Jeep. Since that time I have been amazed by the incredible increase of the population of Jeeps in the United States, seemingly several orders of magnitudes. I contend that, while 1976 sales may have been up, the increase is a perceptual registration of a personal entailment. That is: I tend to notice them, which is our *introduction to personalized systems*.

8. PERSONALIZED DESIGN SYSTEMS

In his chapter, "Factors That Tend to Create Creativity," Osborn [46] devotes a subsection to the idea: "Intimates can encourage best." Lasswell [29] refers to a "warmly indulgent relation between innovator and recognizer." This "climate of indulgence" is confirmed by Dentler and Mackler [12] who conducted tests for originality in undergraduates. In short, the object is *not* to need to eliminate what is likely to be unaccepted by the environment - *not to be on guard*.

This section is not about the love of a mother for her child, a love which unfolds praise and encouragement, a love which sees beauty in the collages and papier-maché brought back from first grade arts and crafts. Instead, I am interested here in notions of acquaintanceship, interpersonal hypotheses, and inferencing making, and how they augment a creative environment and drive a creative person. Is a personalized design system, i.e., an *idiosyncratic* system, the key to the creative use of CAD? I believe so.

Consider a human-to-human encounter with somebody you do not know, maybe from a different culture. The conversation is marked by explicitness, void of both metaphor and short-hand references to shared experiences. The result is a stilted interaction, more bent on the verification of understanding than on the incubation and illumination of ideas. In the extreme, I once likened computer-aided design to discussing Cézanne with a Martian by telegram. My mistake was in subsequently *concentrating on the* telegram (and its limited bandwidth) rather than on *the Martian* (and his/her/its lack of shared experiences).

Work styles are very personal. They seem to get more idiosyncratic the more creative the endeavor (as we have seen with Schiller's rotten apples). While it is hard to think of varying styles of touch-typing, it is easy to imagine inumerable methods of painting or writing poetry and music. For example, we know that Mozart thought out symphonies, quartets and scenes for operas entirely in his *head and then transcribed them onto paper in* their completeness. In contrast, Beethoven wrote fragments *in notebooks and* developed them over years, frequently from clumsy beginnings into miraculous results. Pask and Scott [50] would call Mozart a wholist and Beethoven and serialist. As they (Pask and Scott) have proved with learning strategies, I think we can prove that Mozart and Beethoven would need dramatically different computer-aided scoring systems.

The pitfall is trying to find dichotomies or to search for well-formed taxonomies of style, a pitfall of much of the work in human factors. Yes, people are right-handed or left-handed (or both), and the system should take this dichotomy *into account (which it almost always does not). However, such simple polarities are representative of* thought processes which are developed in great measure out of an entire lifetime of varied, personal and not-easily-sharable experiences. How to reflect these differences in a CAD system and to embody them in specific software and what I have called existential hardware is outside the scope of this paper and is dealt with elsewhere. [40]

Here, let me provide a few examples that range from the superficial to the profound application of personalized techniques, *ranging from the difficult to* the almost-impossible. Consider first handwriting. *Some graphologists*, for example Singer, [61] will go so far as to claim that a full range of cues about personality lie in our mannerisms of dotting *i*'s, crossing *t*'s, slanting *m*'s, etc. While I will not go that far, I will postulate that our *handwritings (for those who still do that) do have* unique signatures and that such signatures are useable for recognizing and discriminating in many inference-making functions. For example, in sketch recognition, with a mechanical design *problem*, we want to separate out projective geometry from annotations, *doodles, shopping lists, or whatever.* Without elaboration, the reader can appreciate that this is immeasurably easier with the added information of who did the writing; easier yet if we can observe the writing on-line (speeds, accelerations, and even pressure); but nevertheless difficult.

Other examples of personalized design strategies include various ways of moving from diagrams to projective geometry, of dealing with classes of problems, or of using preconceptions. They are all personal and progressively more difficult *to incorporate* into a computer aid. Additionally, they grow *and change in conjunction with particular exchanges,* where, for example, two people develop very personal languages of words, gestures, and expressions, frequently specific to a task. I am reminded of a story I cannot document. A painter of some renown was undergoing therapy, frequently doing drawings and making pictograms in the process. His analyst would interpret these, but to no avail therapeutically; the patient progressively got worse, moving ultimately into complete madness. During this time the drawings degenerated slowly, into unrecognizable and deviant *shapes which only the analyst* could decode!

9. THE RETURN OF THE SUNDAY PAINTER

The title of this last section is copied directly from the title of a chapter on "The Future of Computers in the Visual Arts." [39] I am reusing it to convey an aspect of CAD as a *creative* tool, to which I can only call attention, but at this time cannot justify, primarily for cultural reasons. Namely, I am interested in the creativity in Everyman, its amplification by a future of home computers, and its *celebration* by *an important* sense of fulfillment. Matussek [34] speaks of this as driven not by the environment or inherited talent, but by the function of the ego of every human being. Arieti, [1] however, cautions: "Too many of them (people) are so busy protecting themselves from insecurities of neurotic and social origin that they have no energy left for self-expression and growth, especially in the field of innovation."

At this point I must address the creative product, a topic I have cautiously avoided *until now. In my* examples I have loosely moved among the arts and *sciences*, from poetry to chemistry, from painting to physics. They all entail creative processes in the

sense of going beyond that which already exists, but the products are quite different and their bonds with human existence are dissimilar. The product may be an innovation in understanding, a new dimension of utility, a feeling of transcendence, an aesthetic pleasure, or a good laugh. While one is no less important than the other, it is surely in the new dimensions of utility that we see the roots of CAD in engineering. In architectural applications we begin to find islands of subjectivity that form overall archipelagos of individuation. Finally, in the fine arts we are left only with metaphors, to which each person ascribes different meaning.

While it is noticeably unrelated to the innovations of circuit, cam, or even building, I will end with the latter because it affords the opportunity for instrospection and individuality, not just as wishful thinking for the future, but as an extreme, almost outrageous, demand on the man-machine system. Also, computer graphics as we know it and extrapolate it into raster scan technologies [37] is already moving into the home. Walker [68] reports on television-based consumer products: "In the drawing setup, it is possible to program a 'palette' of colors for composing the picture. And this system (Admiral's Videospond) can even perform elementary animation accompanied by audio commentary." For the first years, these devices will be graphical toys of some delight, but of little intellectual challenge or assistance, not unlike computer graphics in its early years in CAD. Then they will emerge as idiosyncratic systems of the most ubiquitous sort, potentially the most widespread amplification of creativity seen by mankind.

Such romantic visions are important fuel for the day daydreams of computer scientists and designers working on CAD. All too often we dwell upon making mechanisms for productivity which, like birth control, are most practicable for our neighbors, not for ourselves. We think of CAD in terms of rooms with raised floors from which one graduates while climbing the managerial ladder of success. Instead, I offer the extreme of the Sunday painter and point at the creative individual. I hope the reader will not look simply at the tip of my finger.

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